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<u>Response to the second written opinion in PCT/DK99/00102.</u>

In response to the written opinion in the above mentioned application, a new set of claims and a new part of the introductory part of the description is hereby submitted.

A copy showing the amendment carried out is also submitted.
It is noted that the page having the hand-written amendments on page 6 submits with letter of 13 March is included in the new part of the introductory part of description.

It is also noted that all amendments do not interfere with art. 24(2) PCT in the sense that the amendment is believed not to go beyond the disclosure in the application as filed.

It is further noted:

Concerning claim 3 it is agreed, that the word difference is not unambiguously derivable from the application since this word is only used on page 11 line 28, from which the wording of claim 3 is not exactly derivable.

In order to overcome this objection it is suggested to use the term " "a signal which is established as a differential signal" in replacement for "the difference".
This expression could be derived from page 12, line 27 - line 34 in the published PCT application, i. q. the application as filed.

Claim 10 has been clarified as shown.

The description is also clarified on the points raised by the examiner.
D1 is identified in the description.

It is now hoped that the application with the proposed amendments can serve as basis for a positive examination report.

Yours faithfully

Ole Jagtboe

A method in the compensation of unlinearities in an amplifier, an amplifier, and uses of the method and the amplifier

The invention relates to a method in the compensation of distortions in an ampflifier which are generated by nonlinearities of the amplifier that consists of a pulse-width modulator wherein a signal is pulse-width modulated to provide a pulse-width modulated small-signal, and wherein the pulse-width modulator has an output controlling a set of change-over switches which feed a load with a pulse-width modulated great-signal by means of a voltage supply.

The invention moreover relates to an amplifier of the type comprising a pulse-width modulator adapted to pulse-width modulate a signal to provide a pulse-width modulated small-signal, said pulse-width modulated signal being fed to at least two change-over switches adapted to connect and disconnect a voltage supply to form a pulse-width modulated great-signal, and having means to compensate for error signals which occur in the signal paths between the pulse-width modulated great-signal and the pulse-width modulated small-signal.

Finally, the invention relates to uses of the amplifier.

Traditional amplifiers for audio uses are used for amplifying audio signals and for forming sound images in loudspeakers. These amplifiers, however, do not have very high efficiencies.

Therefore, amplifiers are being designed according to other principles. These high efficiency amplifiers inclu-

de those which are based on pulse-width modulation. These amplifiers are also referred to as class D amplifiers. Such an amplifier consists of a pulse-width modulator, a set of change-over switches and a low-pass filter.

The principle of a class D amplifier is that two change-over switches are switched to conduct and non-conduct, respectively, depending on the amplitude of a signal, such as an audio signal. The information of the audio signal is hereby converted into a series of pulses whose width corresponds closely to the information of the audio signal.

Instead of two change-over switches, it is possible to use four change-over switches which are caused to conduct and non-conduct in pairs.

Pulse-width modulated amplifiers are theoretically very linear and thereby have a very low distortion, but practical realizations have shown that unlinearities are unfortunately formed in these amplifiers, which has prohibited the use of these as High Fidelity amplifiers unless strong negative feedback systems have been established.

However, establishment of feedback systems in pulse-width modulated amplifiers is not an easy task, since negative feedback performed prior to the low-pass filtering causes much noise in the system.

Furthermore, the load impedance, which is a loudspeaker, is incorporated in the design of the feedback system, and since this impedance may vary depending on loudspeaker selection, the design is thus impeded by the feedback system.

A great part, but not an exclusive part, of the unlinearities in pulse-width modulated amplifiers occurs because the voltage supply to the change-over switches is not constant in the operation of the amplifier. The reason is that the gain in pulse-width modulated amplifiers is derived from the supply voltage to the change-over switches incorporated in the amplifier, divided by the peak voltage of the carrier wave, which is typically a saw-toothed or triangular signal. The gain of the amplifier is thus proportional to the supply voltage, so that variations in it cause a so-called multiplicative error to occur on the output signal from the change-over switches.

A regulated voltage supply may be used to eliminate unlinearities, but a very complex power supply circuit is required for sufficiently linear properties to be achieved, which adds considerably to the costs of the amplifier.

Moreover, it is known that the dead time, which is the time where none of the change-over switches is made, causes distortion of the amplified signal.

It is therefore desirable to reduce the dead time to a minimum in pulse-width modulated power amplifiers. Conversely, less dead time causes problems of increased power consumption and strong ringing on the output signal, because both change-over switches carry current from the supply directly down into earth.

The known methods of linearizing pulse-width modulated amplifiers require strong negative feedback, as mentioned. These methods are particularly unuseful for consumer amplifiers, where design criteria such as low com-

plexity and general usefulness in a broad range of load are important.

EP 0 503 571 A1 discloses a class D amplifier in which variations in the voltage supply are compensated by changing the carrier wave signal as a function of an error in the voltage supply.

Finally US A 5 410 592 discloses a class D ampflier with a specifik feed-back network which produces an error signal that is combined with the audio input signal to form an error compensated audio signal applied to a pulse-width modulator.

On the other hand, other errors that may cause errors in the pulse widths of the pulse-width modulated great-signal will not be included in the compensation.

Accordingly, an object of the invention is to provide a method which is capable of linearizing and compensating for all errors which occur between the signal paths of a pulse-width modulated small-signal and a pulse-width modulated great-signal.

The object of the invention is achieved by the method defined in the introductory portion of claim 1 which is characterized in that the inevitable error, which manifests itself in that the pulse widths of the pulse-width modulated great-signal differ from the pulse widths of the pulse-width modulated small-signal, is detected as an error signal by detecting deviations between the pulse-widths of the modulated great-signal and the pulse-width modulated small-signal, wherein the detected error signal is used to control a carrier signal to the pulse-width modulator.

When, as stated in claim 2, the error signal is detected as a multiplicative error signal, it is relatively easy to modulate the carrier wave signal as a function of the multiplicative error signal.

As stated in claim 3, the detected multiplicative error signal is determined as a signal which is erstablished as a signal between the pulse-width modulated small-signal multiplied by the pulse-width modulated great-signal and the inverted small-signal multiplied by the inverted pulse-width modulated great-signal.
A further circuit-technical advantage is achieved hereby as the compensating circuit both compensates for the multiplicative errors in the pulse width and additionally for the pulse height that occurs in the change-over switches. In addition, a simple implementation of the invention is achieved.
It is noted that the method is particularly suitable for compensating for multiplicative errors in an H-bridge which is operated in class AD operation.

Expediently, as stated in claim 4, the pulse-width modulation is performed by means of a carrier wave signal, which is particularly expedient for use in the pulse-width modulation of analogue signals, when the carrier wave signal is analog.
It is however also possible to use a carrier wave signal that is digital.

For simple circuit design of the pulse-width modulation, it is an advantage if, as stated in claim 5, a sawtoothed or triangular carrier wave signal is used.

When, as stated in claim 6, the slew rate of the carrier wave is adjusted by an external signal, it is ensured

that the gain of the compensated amplifier may be varied over a great range.

As mentioned, the invention also relates to an amplifier.

This amplifier is characterized in that the means for compensating for the error signals are formed by a detector adapted to detect deviations between the pulse widths of the great-signal and of the pullse-width small-signal, and that the output of the detector is connected to a controlled carrier wave generator.

An amplifier is hereby provided in which inevitable unlinearities, which manifest themselves by differences between the pulse-width modulated small-signals and the pulse-width modulated great-signals, may be eliminated without complicated feedback stages.

Expedient embodiments of the amplifier are defined in claims 8-10.

Finally, the invention relates to uses of the method and the amplifier, as mentioned.

The use according to claim 11 allows a much simpler structure to be provided than the negative feedbacks traditionally used in pulse-width modulated amplifiers.

The use according to claim 12 allows the amplifier to be used for the control of resistive and reactive loads, which are e.g. found in electric motors, physical laboratory equipment, measuring apparatus, etc.

The invention will now be explained more fully with reference to an embodiment of the invention shown in the drawing, in which

Patent Claims:

1. A method in the compensation of distortions in an ampflier which are generated by non-linearities of the ampflier that consits of a pulse-width modulator (4), wherein a signal is pulse-width modulated to provide a pulse-width modulated small-signal (5), and wherein the pulse-width modulator (4) has an output controlling a set of change-over switches (6) which feed a load (9) with a pulse-width modulated great-signal (7) by means of a voltage supply (12), characterized in that the inevitable error, which manifests itself in that the pulse widths of the pulse-width modulated great-signal (7) differ from the pulse widths of the pulse-width modulated small-signal (5), is detected as an error signal by detecting deviations between the puls-width of the modulated great-signal and the puls-with modulated small-signal, wherin the detected error signal is used to control a carrier signal to the pulse-width modulator.

2. A method according to claim 1, characterized in that the error signal is detected as a multiplicative error signal.

3. A method according to claim 2, characterized in that the detected multiplicative error signal is determined as a signal which is established as a differential signal between the pulse-width modulated small-signal multiplied by the pulse-width modulated great-signal and the inverted puls-width modulated small-signal multiplied by the inverted pulse-width modulated great-signal.

4. A method according to claims 1-3, character-

i z e d in that the pulse-width modulation is performed by means of a carrier wave signal.

5. A method according to claim 4, c h a r a c t e r - i z e d in that a saw-toothed or triangular carrier wave signal is used.

6. A method according to claim 5, c h a r a c t e r - i z e d in that the slew rate of the carrier wave signal is adjusted with an external signal.

7. An amplifier of the type comprising a pulse-width modulator (4) adapted to pulse-width modulate a signal to provide a pulse-width modulated small-signal (5), said pulse-width modulated small-signal being fed to at least two change-over switches (6) adapted to connect and disconnect a voltage supply (12) to form a pulse-width modulated great-signal, and having means to compensate for error signals which occur in the signal paths between the pulse-width modulated great-signal (7) and the pulse-width modulated small-signal (5), c h a r a c t e r - i z e d in that the means for compensating for the error signals are formed by a detector (10) which is adapted to detect deviations between the pulse widths of the puls-width modulated great-signal and of the puls-width modulated small-signal, and that the output of the detector (10) is connected to a controlled carrier wave generator (11).

8. An amplifier according to claim 7, c h a r a c - t e r i z e d in that the detector (10) is adapted to multiply the pulse-width modulated small-signal with the pulse-width modulated great-signal and to multiply the inverted pulse-width modulated small-signal with the inverted pulse-width modulated great-signal.

9. An amplifier according to claim 7 or 8, c h a r a c t e r i z e d in that the controllable carrier wave generator (11) is adapted to keep the frequency of the carrier wave constant.

10. An amplifier according to claims 7-9, c h a r a c t e r i z e d in that the controllable carrier wave generator (11) is adapted to change the slew rate of the carrier wave on the basis of a detected multiplicative error signal.

11. Use of a method and an amplifier according to claims 1-10 in a negative feedback system.

12. Use of a method and an amplifier according to claims 1-10 for the power control of resistive and reactive loads.